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## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

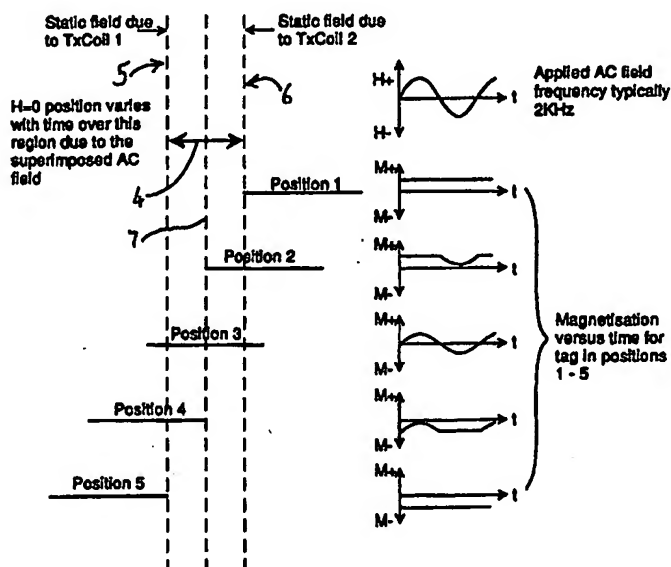
(51) International Patent Classification <sup>6</sup> : <b>G01V 15/00</b>		<b>A1</b>	(11) International Publication Number: <b>WO 96/31790</b>
			(43) International Publication Date: 10 October 1996 (10.10.96)
(21) International Application Number: PCT/GB96/00823			(81) Designated States: AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, JP, KE, KG, KP, KR, KZ, LK, LR, LT, LU, LV, MD, MG, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SI, SK, TJ, TT, UA, US, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).
(22) International Filing Date: 3 April 1996 (03.04.96)			
(30) Priority Data: 9506909.2 4 April 1995 (04.04.95) GB			
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(54) Title: SPATIAL MAGNETIC INTERROGATION

## (57) Abstract

Magnetic tags or markers are disclosed, together with a variety of techniques by means of which such tags may be interrogated. In one aspect, the magnetic marker or tag which is characterised by carrying a plurality of discrete magnetically active regions in a linear array. In another aspect, the invention provides a method of interrogating a magnetic tag or marker within a pre-determined interrogation zone, the tag comprising a high permeability magnetic material, for example to read data stored magnetically in the tag or to use the response of the tag to detect its presence and/or to determine its position within the interrogation zone, characterized in that the interrogation process includes the step of subjecting the tag sequentially to: (1) a magnetic field sufficient in field strength to saturate the high permeability magnetic material, and (2) a magnetic null as herein defined. Applications of such techniques are described, *inter alia*, in relation to (a) identifying articles to which tags are attached; (b) accurate determination of position, as in the location of surgical probes; and (c) totalisation of purchases, where each item carries a tag coded with data representing its nature and its price.

## Signals from tag at different positions with respect to null plane



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## AMENDED CLAIMS

[received by the International Bureau on 25 September 1996 (25.09.96);  
original claims 1-46 replaced by amended claims 1-53 (11 pages)]

1. A magnetic marker or tag which is characterised by  
carrying a plurality of discrete magnetically active  
5 regions in a linear array.
2. A tag as claimed in claim 1, characterised in that  
said discrete magnetically active regions are supported  
on a substrate.
- 10 3. A tag as claimed in claim 1 or 2, characterised in  
that said discrete magnetically active regions are  
formed from a continuous strip or layer of magnetisable  
material discrete regions of which are magnetised and  
15 the space(s) between said magnetically active regions  
are non-magnetised.
4. A tag as claimed in claim 3, characterised in that  
said layer of magnetisable material is carried by a  
20 continuous strip of a magnetically active material.
5. A tag as claimed in claim 1, 2, 3 or 4,  
characterised in that the tag has two or more linear  
arrays of magnetically active regions.
- 25 6. A tag as claimed in claim 5, characterised in that  
the tag has two linear arrays disposed orthogonally.
7. A tag as claimed in any preceding claim,  
30 characterised in that each of the magnetically active  
regions is of substantially the same shape and size.
8. A tag as claimed in any preceding claim,  
characterised in that the spacing between each of the  
35 magnetically active regions is uniform.

## 47

9. A tag as claimed in any one of claims 1 to 7, characterised in that the spacing between each of the magnetically active regions is non-uniform.
- 5 10. A tag as claimed in any preceding claim, characterised in that it is in the form of a relatively long, thin strip having a preferential axis of magnetisation along its length.
- 10 11. A tag as claimed in any preceding claim, characterised in that the magnetically active regions are formed of a thin film, spin-melt material having a preferential axis of magnetisation, the preferential axes of magnetisation being aligned within the (or  
15 each) linear array.
12. A tag as claimed in claim 10, characterised in that the preferential axes of magnetisation are generated by longitudinal annealing of the thin film,  
20 spin-melt material.
13. A method of interrogating a magnetic tag or marker within a predetermined interrogation zone, the tag comprising a high permeability magnetic material, for  
25 example to read data stored magnetically in the tag or to use the response of the tag to detect its presence and/or to determine its position within the interrogation zone, characterised in that the interrogation process includes the step of subjecting  
30 the tag sequentially to: (1) a magnetic field sufficient in field strength to saturate the high permeability magnetic material, and (2) a magnetic null as herein defined.
- 35 14. A method as claimed in claim 13, characterised in that said magnetic null is caused to sweep back and

forth over a predetermined region within the interrogation zone.

15. A method as claimed in claim 13 or 14,  
5 characterised in that (a) said magnetic null lies in a plane; and (b) the saturating field occurs adjacent to said plane.
- 10 16. A method of determining the presence and/or the position of a magnetic element within a predetermined interrogation zone, the magnetic element having predetermined magnetic characteristics, which method is characterised by the steps of: (1) establishing within  
15 said interrogation zone a magnetic field pattern which comprises a relatively small region of zero magnetic field (a magnetic null) contiguous with regions where there is a magnetic field sufficient to saturate the, or a part of the, magnetic element (the saturating  
20 field), said relatively small region being coincident with a region through which the magnetic element is passing, or can pass, or is expected to pass; (2) causing relative movement between said magnetic field and said magnetic element such that said magnetic null  
25 is caused to traverse at least a part of the magnetic element in a predetermined manner; and (3) detecting the resultant magnetic response of the magnetic element during said relative movement.
- 30 17. A method of identifying a magnetic element which possesses predetermined magnetic characteristics, which method is characterised by the steps of: (1) subjecting the magnetic element to a first magnetic field which is sufficient to induce magnetic saturation in at least a  
35 part of the magnetic element; (2) next subjecting the magnetic element to conditions of zero magnetic field

(i.e. a magnetic null), the zero field occupying a relatively small volume and being contiguous with said first magnetic field; (3) causing relative movement between the applied magnetic field and said magnetic  
5 element such that said magnetic null is caused to traverse at least a part of the magnetic element in a predetermined manner; and (4) detecting the resultant magnetic response of the magnetic element during said relative movement.

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18. A method according to claim 17, characterised in that said magnetic element is caused to traverse an interrogation zone within which the required magnetic conditions are generated.

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19. A method of identifying a magnetic element, the magnetic element having predetermined magnetic characteristics, which method is characterised by the steps of: (1) causing the magnetic element to enter an  
20 interrogation zone within which there is established a magnetic field pattern which comprises a relatively small region of zero magnetic field (a magnetic null) contiguous with regions where there is a magnetic field sufficient to saturate the, or a part of the, magnetic  
25 element (the saturating field); (2) causing the magnetic element to be moved through the saturating field until it reaches the magnetic null; (3) causing relative movement between said magnetic field and said magnetic element such that said magnetic null is caused  
30 to traverse at least a part of the magnetic element in a predetermined manner; and (4) detecting the resultant magnetic response of the magnetic element during said relative movement.

35 20. A method according to claim 16, 17, 18 or 19, characterised in that said relative movement is

produced by sweeping the applied magnetic field over the magnetic element.

21. A method according to any one of claims 13 to 20,  
5 characterised in that said magnetic element is generally elongate and in that the zero field direction of said magnetic null is arranged to extend along the major axis of said magnetic element.
- 10 22. A method according to any one of claims 13 to 20, characterised in that said magnetic element is in the form of a thin film and in that the zero field direction of said magnetic null is arranged to be aligned with the axis of magnetic sensitivity of the  
15 film.
23. A method as claimed in any one of claims 13 to 22, characterised in that said magnetic field or magnetic field pattern is established by the application to said  
20 spatial volume or to said interrogation zone of two magnetic fields of opposite polarity.
24. A method as claimed in claim 23, characterised in that the application of said two magnetic fields is  
25 achieved by use of one or more coils carrying direct current.
25. A method as claimed in any one of claims 13 to 24, characterised in that said magnetic field or magnetic  
30 field pattern is established by the use of one or more permanent magnets.
26. A method according to claim 24, characterised in that said coil(s) carry/carries a substantially  
35 constant current so as to maintain the magnetic null at a fixed point.

27. A method according to claim 24, characterised in that said coil(s) carry/carries a current whose magnitude varies in a predetermined cycle so that the position of the magnetic null is caused to oscillate in a predetermined manner.

28. A method according to claim 25, characterised in that said permanent magnet(s) is or are accompanied by a coil or coils which carry or carries a current whose magnitude varies according to a predetermined cycle so that the position of the magnetic null is caused to oscillate in a predetermined manner.

29. A method as claimed in any one of claims 16 to 28, characterised in that said relative movement is caused by the application to said magnetic field or magnetic field pattern of an alternating magnetic field.

30. A method of determining the presence and/or the position of a magnetic element, which is characterised by the steps of: (1) applying a magnetic field to a region where the magnetic element is, or is expected to be, located, said magnetic field comprising two opposed field components, generated by at least one magnetic field source, which result in a null field at a predetermined position; (2) causing relative movement between said magnetic field and said magnetic element; and (3) detecting the resultant magnetic response of the magnetic element during said relative movement.

31. A method according to claim 29 or 30, characterised in that relative movement between said magnetic field and said magnetic element is caused by applying a relatively low amplitude alternating magnetic field superimposed on a DC field.

32. A method according to claim 31, characterised in that said relatively low amplitude alternating magnetic field has a frequency in the range from 10Hz to 100kHz.

5 33. A method according to any one of claims 13 to 32, characterised in that detection of the magnetic response of said magnetic element comprises observation of harmonics which are generated by the magnetic element from an applied AC field as its magnetisation  
10 state is altered by passing through the magnetic null.

34. A method of determining the precise location of an object, characterised in that the method comprises: (a) securing to the object a small piece of a magnetic  
15 material which is of high magnetic permeability; (b) applying to the region in which said object is located a magnetic field comprising two opposed field components, generated by magnetic field sources, which result in a null field at a position intermediate said  
20 magnetic field sources; (c) applying a low amplitude, high frequency interrogating field to said region; (d) causing the position of the null field to sweep slowly back and forth over a predetermined range of movement; (e) observing the magnetic interaction between said  
25 applied magnetic field and said small piece of magnetic material; and (f) calculating the position of the object from a consideration of said magnetic interaction and from the known magnetic parameters relating to said applied field and to said small piece  
30 of magnetic material.

35. A method according to claim 34, characterised in that said object is a surgical instrument.

35 36. A method according to claim 35, characterised in that said object is a surgical probe or needle.

## 53

37. A method according to claim 34, 35 or 36, characterised in that said small piece of high magnetic permeability magnetic material is in the form of a thin foil, a wire or a thin film.

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38. A method according to any one of claims 34 to 37, characterised in that said magnetic field sources are coils.

10 39. A method according to any one of claims 34 to 37, characterised in that one or both of said magnetic field sources is/are permanent magnet(s).

15 40. A method according to any one of claims 34 to 39, characterised in that the applied magnetic field is generated by three sets of mutually orthogonal magnetic field sources.

20 41. A method according to claim 39 or 40, characterised in that the applied magnetic field is generated by operating sequential field scans and calculating, for each scan, the position of the centre of the harmonic output from the magnetic material.

25 42. A method according to claim 41, characterised in that there are nine sequential field scans, operated according to the following table, in which the magnetic field sources are identified as a, b and c and the scans are numbered from 1-9 (scanning order being of no  
30 significance):

	Orthogonal field source	1	2	3	4	5	6	7	8	9
5	a	ON	ON	ON	OFF	OFF	ON	OFF	OFF	ON
	b	OFF	ON	OFF	ON	ON	ON	OFF	ON	OFF
	c	OFF	OFF	ON	OFF	ON	OFF	ON	ON	ON

10 43. A method according to claim 40, characterised in  
that three orthogonal coil sets are continuously  
excited so as to create a continuously rotating field  
direction which covers the volume of interest in  
controlled sweeps of predetermined width.

15

44. A method of coding and/or labelling individual  
articles within a predetermined set of articles by  
means of data characteristic of the articles, e.g.  
article price and/or the nature of the goods  
20 constituting the articles, which method is  
characterised by applying to each article a magnetic  
tag or marker carrying a predetermined arrangement of  
magnetic zones unique to that article or to that  
article and others sharing the same characteristic,  
25 e.g. article price and/or the nature of the goods  
constituting the article, said magnetic tag or marker  
being susceptible to interrogation by an applied  
magnetic field to generate a response indicative of the  
magnetic properties of the tag or marker and hence  
30 indicative of the nature of the article carrying the  
magnetic tag or marker.

45. A method according to claim 44, characterised in  
that said magnetic tag or marker comprises a plurality  
35 of magnetic zones each displaying high permeability.

46. A method according to claim 45, characterised in that each magnetic zone can be magnetically biased by means of a second layer of medium-coercivity magnetic material.

5

47. A method of totalising data (e.g. prices) from an assembly of individual articles each carrying a magnetic tag as claimed in any one of claims 1 to 11, the tags carrying data representative of a specific  
10 characteristic (e.g. price) of the article to which they are attached, characterised in that the assembly of articles is caused to move through an interrogation zone where the assembly is subjected to a method as claimed in any one of claims 39 to 42; and processing  
15 the signals received during said method to generate the required summing of individual datum values.

48. A device for reading a magnetic tag, which device comprises a plurality of permanent magnets disposed in  
20 a circular array around a gap through which a tag to be read can pass, the poles of said permanent magnets being disposed so that each of the magnets has its pole of one polarity (for example North) positioned on the inside of the circular array, and its pole of the  
25 opposite polarity (for example South) positioned on the outside of the circular array; and a coil disposed coaxially with said circular array adjacent to said permanent magnets.

30 49. A device for reading a magnetic tag, which device comprises a plurality of permanent magnets disposed in a circular array around a gap through which a tag to be read can pass, the permanent magnets being disposed such that for each of them its magnetic poles lie on an  
35 imaginary line extending radially outwardly from the centre of said circular array, poles of one given

## 56

polarity all being positioned radially inwardly and poles of the opposite polarity all being positioned radially outwardly of the array; and a coil disposed within said circular array adjacent to said permanent  
5 magnets.

50. A device as claimed in claim 48 or 49, wherein said circular array of permanent magnets consists of an even number of permanent magnets.

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51. A device as claimed in claim 48, 49 or 50, wherein said permanent magnets are polymer-bonded ferrite magnets.

15 52. A position sensor which includes a device as claimed in claim 48, 49, 50 or 51.

53. Apparatus for interrogating a magnetically coded tag, which apparatus is characterised by an electrical  
20 circuit which comprises a source of energy at frequency  $2f$  and output means for providing an electrical output, said source being coupled to said output means by (i) means for halving the frequency of said source energy; (ii) first filter means arranged substantially to  
25 reject energy at frequency  $2f$ ; (iii) tuned circuit means tuned to energy at frequency  $f$  and including a transmitter coil adapted to radiate energy towards a magnetically coded tag positioned so as to be  
influenced by said radiated energy and a receiver coil  
30 (which may be the same coil as said transmitter coil) for receiving energy radiated by the tag in response to the received energy; and (iv) second filter means arranged substantially to reject energy at frequency  $f$  and to pass energy at frequency  $2f$ , and wherein said  
35 output means is arranged to provide an output which is a function of the phase difference between the source and the output of said second filter means.